

Optics - Division B
Cobra Invitational
2018 Science Olympiad
02/03/2018

School Name: _____

Team Name: _____ Team Number: _____

Team Members: _____

Test Instructions -

- Carefully read the rules below
- Clearly write your school name and team information.
- Do not turn this page until told to do so.
- Follow instructions to Start and Stop the exam.
- Go to the laser shoot station quietly, when asked to do so and return back to continue the exam.
- No electronic devices except calculators are allowed.
- All work must be legible and you must show your work to receive maximum points. Only partial points will be awarded for correct answers if the calculation steps are missing.
- Answer must be in metric unit. Answers without units will be considered incorrect.

60 points total – 24 multiple choice, 11 fill-in the blanks, 15 numerical, 10 drawing, 5 tie-breaker

MULTIPLE CHOICE QUESTIONS (1 points each)

Instruction: Circle the best possible answer from the four choices –

1. Electromagnetic waves consist of:
(A) Compressions and rarefactions of electromagnetic pulses.
(B) Oscillating electric and magnetic fields.
(C) Particles of light energy.
(D) High-frequency gravitational waves.
2. The threshold frequency of a photo emissive surface is 7.0×10^{14} hertz. Which electromagnetic radiation, incident upon the surface, will produce the greatest amount of current?
(A) Low intensity infrared radiation
(B) High intensity infrared radiation
(C) Low intensity UV radiation
(D) High intensity UV radiation
3. Sun appears white at noon but orange/red in the evening because
(A) Reflected light from the Moon interferes with the sunlight
(B) Clouds in the horizon give sunlight orange/red color
(C) Most of the blue light is scattered away and only orange/red light remains
(D) Temperature of the Sun drops in the evening
4. Which of these electromagnetic waves has the shortest wavelength?
(A) Radio waves.
(B) Infrared waves.
(C) X-rays.
(D) Ultraviolet waves.
(E) Light waves.
5. Infrared waves are often called heat waves because they:
(A) Emanate from relatively hot sources.
(B) Consist of frequencies lower than those of visible light.
(C) Induce resonance in molecules and increase the internal energy in a substance.
(D) Are absorbed rather than reflected by the skin.
(E) Are the predominant waves emitted by the sun
6. Sunburns are produced by which of the following?
(A) Ultraviolet light.
(B) Visible light.
(C) Infrared light.
(D) All the above.
(E) None of the above.

7. Materials generally become warmer when light is:
- (A) **Absorbed by them.**
 - (B) Reflected by them.
 - (C) Transmitted by them.
 - (D) All of the above.
 - (E) None of the above.
8. Your coat looks magenta in white light. What color does it appear in green light?
- (A) Green
 - (B) **Black**
 - (C) Blue
 - (D) Yellow
 - (E) Red
9. The temperature of the Earth is around 290 K. At which wavelength is the Earth thermally emitting the most light? (Assume Wien's displacement constant $3 \times 10^{-3} \text{ m K}$)
- (A) **$10.3 \text{ } \mu\text{m}$.**
 - (B) 500 nm.
 - (C) 760 nm.
 - (D) 390 nm.
 - (E) 250 mm.

10. The circles around a star shown in the picture is called –

- (A) **Airy pattern**
- (B) Halo effect
- (C) Newton's ring
- (D) Star force
- (E) None of the above

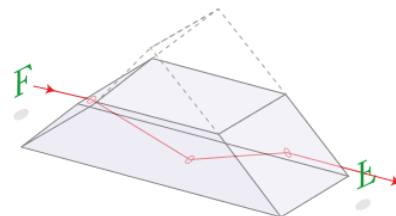


11. Which of the following statement is correct?

- (A) S-Polarized refers to light polarized perpendicular to the plane of incidence
- (B) P- Polarized refers to light polarized parallel to the plane of incidence
- (C) P- Polarized refers to light that is partially polarized.
- (D) **Both A and B**
- (E) Both B and C

12. The prism shown in the picture is a

- (A) Porro prism
- (B) **Dove prism**
- (C) Penta prism
- (D) Amici roof prism
- (E) None of the above



13. Light from a distant object like the Sun is reflected from a concave mirror. Where will the reflected rays converge?

- (A) **At the focal point.**
- (B) At the center of curvature.
- (C) At the mirror surface.
- (D) Far from the mirror.
- (E) They do not converge.

14. Car side view mirrors on the passenger door usually say; "Objects in the mirror are closer than they appear." What type mirror is this?

- (A) Concave
- (B) **Convex**
- (C) Plane
- (D) None of them

15. What is the index of refraction for an object in which light travels at 1.97×10^8 m/s.

- (A) .77
- (B) **1.52**
- (C) 1.05
- (D) 2.3

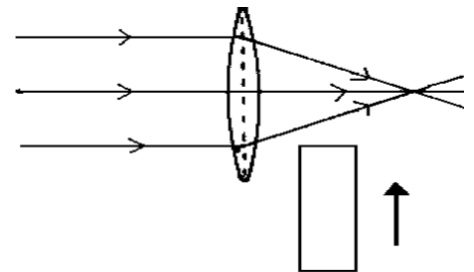
16. A survivor from a ship wreck sees an image of a fish in the water. To catch it with her spear, she must

- (A) Aim above the image of the fish
- (B) **Aim below the image of the fish**
- (C) Aim at the image of the fish
- (D) Put away the spear and use a fishing rod

17. A block of glass is pushed into the path of the light, as shown below.

The point where the light rays cross will

- (A) Stay in the same place
- (B) Move to the left
- (C) **Move to the right**
- (D) Shift up
- (E) Shift down



18. What is the focal length of a thin lens with a lens power of 2.25 diopters

- (A) 2.25 m
- (B) 225 mm
- (C) **0.444 m**
- (D) 1.5 cm
- (E) 100 mm

19. The proper name for farsightedness is
- (A) Hyperopia**
 - (B) Presbyopia
 - (C) Astigmatism
 - (D) Myopia
 - (E) Glaucoma
20. The sensation of color is seen when light falls on the eye's:
- (A) Rods.
 - (B) Cones**
 - (C) Both.
 - (D) Neither.
21. Information-carrying nerves are connected to the retina at:
- (A) The fovea.
 - (B) The blind spot.**
 - (C) The cornea.
 - (D) The iris.
 - (E) The periphery.
22. The critical angle for diamond ($n = 2.42$) submerged in water ($n = 1.33$) is
- (A) 33 Degrees**
 - (B) 49 Degrees
 - (C) 24 Degrees
 - (D) 17 Degrees
 - (E) None of the above
23. Astronomers can tell whether a star is approaching or receding from the earth by:
- (A) Its temperature.
 - (B) Its change in temperature.
 - (C) Its absorption spectra.
 - (D) The Doppler Effect.**
 - (E) All of the above.
24. Which wave has the highest speed in vacuum?
- (A) Gamma Rays
 - (B) Ultraviolet rays
 - (C) Light wave
 - (D) X-rays
 - (E) All mentioned above have same speed**

FILL IN THE BLANKS QUESTIONS (1 points each)

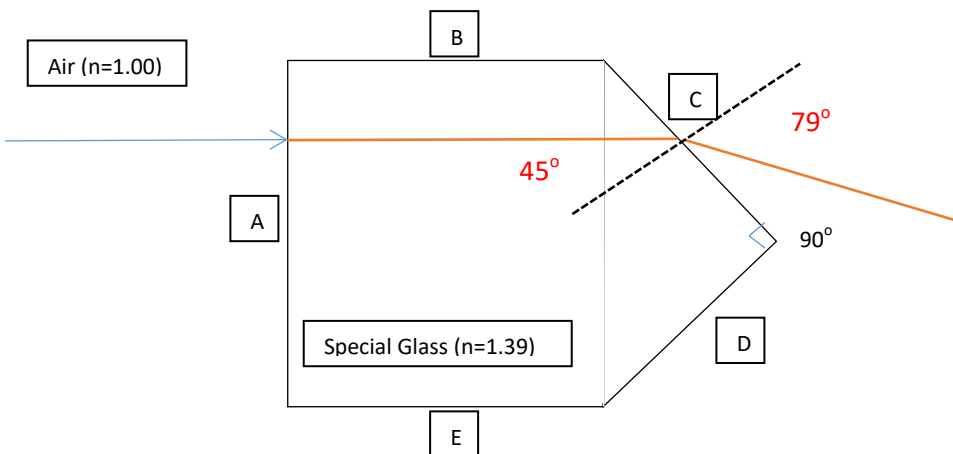
Instruction: Write your answer in the blank space to complete the sentence –

25. Rhodopsin (a light-sensitive receptor protein involved in visual photo transduction) is found in the _____ **rod** _____ cells of the human eye.
26. _____ **Blind spot** _____ is the common term for the punctum caecum.
27. The iris regulates the amount of light going into the eye by changing the size of _____ **pupil** _____.
28. _____ **Presbyopia** _____ is the Eye condition when eyes gradually lose the ability to see things clearly up close. It is due to hardening of the _____ **lens** _____ of the eye
29. Describe the effect of alterations in d , L and λ upon the spacing between bright spots in a two-point source interference pattern; complete the following statements. (3 points)
- (A) Altering the distance between sources (d) by a factor of 2 would cause the y value to _____ **decrease** _____ (increase or decrease) by a factor of **2**.
- (B) Altering the distance between sources (d) by a factor of 0.5 (one-half) would cause the y value to _____ **increase** _____ (increase or decrease) by a factor of **2**.
- (C) Altering the wavelength of light (λ) by a factor of 1.5 (three-halves) would cause the y value to _____ **increase** _____ (increase or decrease) by a factor of **1.5**.

NUMERICAL QUESTIONS (5 points each) –

Instruction: Show your calculation and draw a circle around the final answer(s) –

30. A ray of light is traveling through air ($n = 1.00$) towards a special glass block ($n = 1.39$) in the shape shown below. The ray of light is perpendicular to surface A. Which surface the light will come out? (1 point)
Calculate the critical angle. (1 point) Draw the ray diagram to show the reflection/refraction/total-internal-reflection and label the angle values. (3 points)



The light will come out of the surface C.

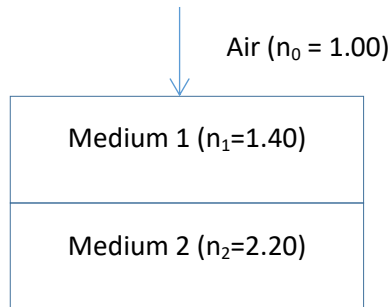
Critical angle $\Rightarrow \arcsin(1/1.39) = 46.01^\circ$

Angle of incidence on surface C = 45°

$(1.39) \times \sin(45^\circ) = (1.0) \times \sin \theta$

Angle of refraction = $\theta = \arcsin((1.39) \times \sin(45^\circ)) = 79.38^\circ$

31. Light passes through a transparent dielectric medium at normal incidence ($\Theta_i=0$) with a refraction index (n_1) of 1.40, then another with refraction index (n_2) 2.20. If the starting index (n_0) was 1.00, what percent of the original amplitude is transmitted through the second medium? (3 points)



With $\Theta_i=0$, using the Fresnel equations for transmittance T

$$T = \frac{4n_i n_t}{(n_i + n_t)^2}$$

Transmittance between air and medium 1 = $(4 \times 1.4) / (2.4)^2 = 97.22\%$

Transmittance between medium 1 and medium 2 = $(4 \times 1.4 \times 2.2) / (1.4 + 2.2)^2 = 95.06\%$

Total transmittance = $97.22\% \times 95.06\% = 92.41\%$

32. A 4.00-cm tall light bulb is placed a distance of 35.5 cm from a diverging lens having a focal length of -12.2 cm. Determine the image distance and the image size. (2 points)

Using $1/f = 1/D_o + 1/D_i$ and $m = H_i/H_o = -D_i/D_o$

$f = 12.2$ cm, $D_o = 35.5$ cm and $H_o = 4$ cm

$D_i = -9.08$ cm

$H_i = 1.02$ cm

33. What is the energy of the photon and the wavelength of the photon emitted when an electron goes from $n=6$ to $n=3$ in a hydrogen atom? (3 points)

Rydberg constant for hydrogen atom (R_H) = 2.179×10^{-18} Joules

Planck constant (h) = 6.63×10^{-34} m² kg / s

$$\Delta E = -R_H (1/n_1^2 - 1/n_2^2)$$

$$\Delta E = -2.179 \times 10^{-18} \times ((1/3^2) - (1/6^2)) = -2.179 \times 10^{-18} \times ((1/9) - (1/36)) \text{ J} = -1.816 \times 10^{-19} \text{ J}$$

$$E = hc / \lambda$$

$$\lambda = hc / \Delta E = ((6.63 \times 10^{-34} \text{ m}^2 \text{ kg} / \text{s}) (3 \times 10^8 \text{ m/s})) / (1.816 \times 10^{-19} \text{ J}) = 10.95 \times 10^{-7} \text{ m} = 1095 \text{ nm}$$

34. The human pupil at its widest has a diameter of around 9 millimeters. What its spatial resolution for a blue object ($\lambda = 700$ nanometers) 6 meters away? (2 points)

Angular resolution (Θ) for wavelength (λ) and lens aperture (D) is

$$\theta = 1.220 \frac{\lambda}{D}$$

$$\Theta = 1.22 \times (700 \text{ nm} / 9 \text{ mm}) = 0.95 \times 10^{-4}$$

$$\text{Spatial resolution } (\Delta l) = \Theta L = 0.95 \times 10^{-4} \times 6 \text{ m} = 0.5693 \text{ mm}$$

DRAWING QUESTIONS (5 points each) –

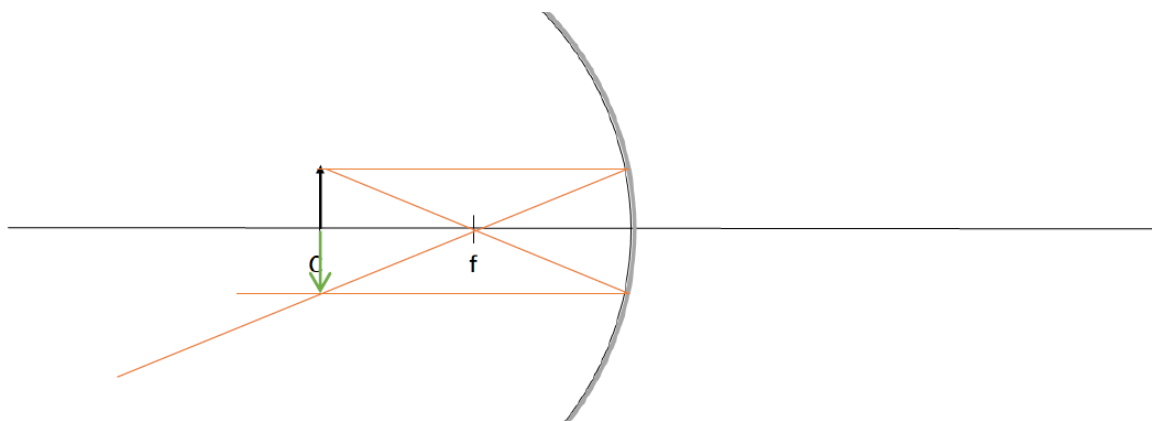
Instruction: Drawing should be to scale and angles should be accurate –

35. Draw the images of the Arrow line in the following curved mirror **(2 points)**. Specify the location, orientation, type of the image **(3 points)**.

Location = _____ In front of the mirror at the center of curvature _____

Orientation = _____ Inverted _____

Type = _____ Real _____

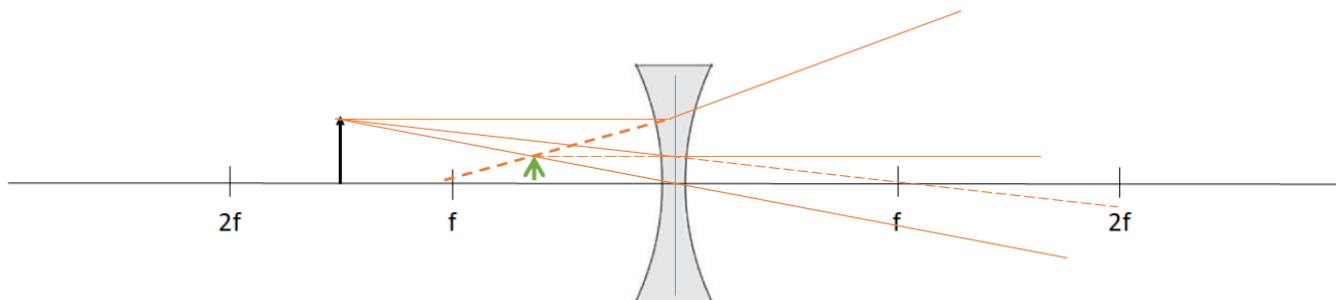


36. Draw the ray diagram for the object located in front of a diverging lens? **(2 points)**. Specify the location, orientation, type of the image **(3 points)**.

Location = _____ Between f and the lens _____

Orientation = _____ Upright _____

Type = _____ Virtual _____



Tie Breaker (5 points)

37. In atmospheric optics, ice crystals act as prisms on light from the Sun or Moon. If they have an apex angle of exactly 60° , what is their angle of minimum deviation? Refractive index of ice crystals = 1.31 (5 points)

Prism of apex angle (σ) = 60°

Prism index of refraction (n_{prism}) = 1.31

Air refractive index (n_0) = 1.00

Assume angle of minimum deviation = δ

Using the following formula

$$\frac{n_{\text{prism}}}{n_0} = \frac{\sin \frac{1}{2}(\sigma + \delta)}{\sin \frac{1}{2}\sigma}$$

$$\delta = 21.84^\circ$$